What does a Negawatt Really Cost?

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DISCUSSION PAPER
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ABSTRACT

We use data from ten utility conservation programs to calculated the cost per Kwh of electricity saved---the cost of a "negawatthour"----resulting from these programs. We first compute the life-cycle cost per Kwh saved based on utility experience and expectations associated with these conservation programs. The resulting figures indicate that the cost of a negawatthour is substantially higher than previously suggested by standard sources such as Lovins and EPRI which are routinely cited by policymakers. The costs calculated for residential programs in particular are much higher than conservation advocates have suggested. We find substantial variation in costs for similar programs between utilities as well as significant intra-utility variation in the cost per kWh saved for specific sub-programs. Some of these programs appear to be uneconomical even before correcting for biases in utility cost accounting and in the measurement of actual electricity savings. The bulk of the expenditures and savings from the utility conservation programs we reviewed are associated with subsidies for commercial and industrial conservation investments rather than for conservation investments made by residential customers. Furthermore, it is likely that the values for the cost per kWh saved that we derive from utility reports understate their true costs by a factor of two or more on average. The actual costs per kWh saved are likely to be significantly higher, on average, than those computed from utility reports because utilities frequently fail to count important cost elements. They also frequently fail to base their estimates of the electricity saved by the programs on ex post measurement of consumer behavior, relying instead on notoriously inaccurate ex ante engineering estimates. Better utility cost accounting procedures and the development and use of sound sampling and statistical methods to measure the electricity savings actually achieved by utility conservation efforts is essential to ensure that only cost-effective conservation programs are pursued and to protect electricity ratepayers from excessive costs.

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[1] Department of Economics, MIT. We are grateful for financial support from the MIT Center for Energy Policy Research (Joskow and Marron) and the National Science Foundation (Marron). We are also grateful to the many people at the utilities that we surveyed who provided us with the information that we relied upon for this study. The analysis presented here is solely the responsibility of the authors.

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I. INTRODUCTION

It is widely believed that significant cost-effective opportunities exist for consumers to use electricity more efficiently. In this context it is often argued that there are many conservation opportunities for which the life-cycle cost of investing in energy efficiency is significantly less than the resulting savings in electricity costs. Amory Lovins of the Rocky Mountain Institute, the most quoted, and quotable, proponent of this view, estimates that end-use electricity efficiency in the United States can be increased by as much as 70% at an average life-cycle cost of only 0.6 cents per kWh saved. The Electric Power Research Institute (EPRI), a research organization funded by the electric utility industry, estimates that end-use electricity efficiency can by increased by almost 30% at an average life-cycle cost of roughly 2.6 cents per kWh saved (both costs are from Fickett, Gellings, and Lovins 1990). See Figure 1.

These numbers reflect the "gross" life-cycle costs of adopting more efficient electric appliances and equipment -- what Lovins has dubbed the cost

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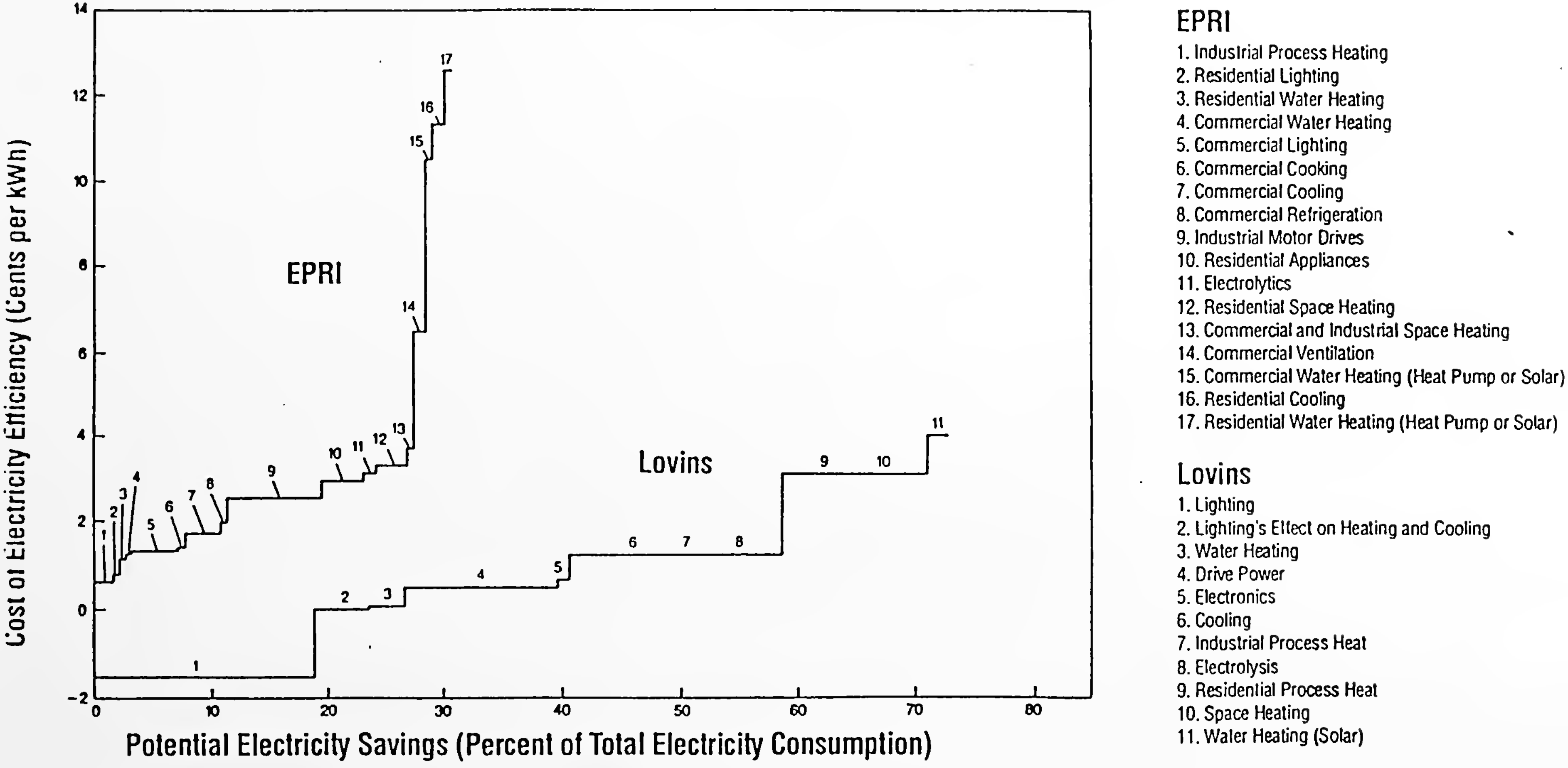
[1] Department of Economics, MIT. We are grateful for financial support from the MIT Center for Energy Policy Research (Joskow and Marron) and the National Science Foundation (Marron). We are also grateful to the many industry representatives who provided us with the information necessary for this study. The views expressed here are those of the authors.

Figure 1: Potential Electricity Savings



Reproduced from Alfred E. Kahn, "Rational Least-Cost Planning," The Electricity Journal, June 1991, page 14 of a "negawatt".[2] That is, they represent the life-cycle cost of investing in conservation before accounting for the resulting savings in electricity costs. To calculate the net economic benefit of these conservation expenditures, we must subtract from them the production costs of the electricity they displace. While avoided electricity costs vary greatly depending on customer utilization characteristics, the type of conservation measures, and geographic location, a comparison of the Lovins and EPRI estimates of the cost per kWh saved with average U.S. electricity prices is instructive. In 1990, the average residential electricity price was about 8 cents per kWh and the average industrial price was about 5 cents per kWh (Energy Information Administration (1991), p. 48). Prices vary between the sectors because of differences in their demand characteristics.

Since these prices are expected to be roughly constant in real terms over the next ten years (Energy Information Administration (1991), p. 48), it is clear that the Lovins and EPRI estimates both suggest that large opportunities exist for cost-effective (i.e. positive net benefits) improvements in end-use electric efficiency.[3] If consumers took advantage of

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[2] To be precise, these figures represent the cost of a "negawatthour". Whereas watts, and hence "negawatts", refer to units of electric capacity, watthours, and hence "negawatthours", refer to electric energy, the focus of our analysis. In keeping with the standard lingo, however, we use the more common term "negawatt" to refer to both capacity and energy.

[3] Note that the electricity prices are cited only to provide an indication of the magnitude of the difference between the projected costs and benefits of conserving electricity. Actual savings from particular measures or programs would, of course, vary, depending on utility characteristics as well as the characteristics of the specific conservation options, particularly the relative contributions on-peak (where capital and operating costs would be saved) and off-peak (where only operating costs would be saved). Average fuel and variable operations and maintenance costs tend to be about 2 to 3 cents per kWh, thus accounting for the bulk of off-peak electricity prices. A new base-loaded natural gas-fired combined-cycle generating unit produces electricity at a cost of about 5 to 6 cents per kWh.

these opportunities they would, in the long run, both save money and reduce the rate of growth (or even absolute level) of electricity consumption. Such a reduction in electricity demand would, in turn, reduce the future negative impacts of electricity production on the environment.

The Lovins and EPRI estimates of abundant economical opportunities to increase end-use electricity efficiency are having important effects on both energy and environmental policy. The National Academy of Sciences relied heavily on both the Lovins and EPRI energy efficiency "supply curves" in developing recommendations for a set of "no regrets" policies to respond to global warming concerns (National Academy of Sciences (1991)). More importantly for our purposes, a growing number of state public utility commissions have ordered utilities to develop programs that provide subsidies to encourage consumers to make qualified electricity conservation investments. In 1990 we estimate that electric utilities spent between $1.0 to $2.0 billion on these electricity conservation programs, roughly 1% of revenues.[4] However, expenditures on conservation are increasing rapidly. Consolidated Edison Company of New York expects to spend over $4 billion of conservation through 2008 and Pacific Gas and Electric expects to spend $1 billion to $2 billion over the next five years (Wall Street Journal, November 5, 1990, p. B1). Advocates of utility conservation programs envision as much as $165 billion of utility expenditures over the next ten to fifteen years (Hirst (1991)). The costs of these programs are recovered by electric utilities from their captive customers as higher electricity prices through the public utility ratemaking process.

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[4] We distinguish here between conservation programs designed to increase end-use energy efficiency and so-called load management programs that shift consumption from peak to off-peak periods.

Many economists, however, have expressed considerable skepticism regarding the more extreme estimates of the cost of electricity conservation. When electricity consumers invest in more efficient appliances and equipment they reduce their electricity consumption and their electricity bills. At the cost and price levels noted above, consumers should, in the long run, find it to be in their self-interest to adopt many of the "untapped" conservation opportunities identified by Lovins and EPRI. While it is not surprising that all consumers are not operating on the efficiency frontier, the gap implied by these numbers is surprisingly large. There is after all abundant econometric evidence that the demand for electricity slopes downward, that appliance and fuel choices are sensitive to energy prices, and that the energy efficiency of U.S. industry has increased significantly over the last two decades.

On the other hand, advocates of aggressive utility-financed subsidy programs for electricity conservation, as well as government mandated appliance efficiency standards, tightened building codes, etc., argue that consumers are not taking advantage of these economical conservation opportunities because of a long list of market imperfections (for a discussion of these imperfections see, for example, Fisher and Rothkopf 1989). They argue further that the provision to consumers of information and, more importantly, financial subsidies is required to overcome these barriers and that electric utilities are in the best position to do both. Whether electric utilities are in a good position to provide these services because they actually have unique skills and capabilities or because, as regulated monopolies, the associated costs can be easily passed on to customers (i.e., taxation by regulation) is a subject of some dispute.

It is not the purpose of this paper to try to resolve the disputes about the significance of these market imperfections or the wisdom of requiring utilities to respond to them by subsidizing conservation. Indeed, the authors have somewhat different views on these issues. Rather, we have a more modest goal in this paper. We seek to determine what we actually know about how much it costs utilities and their customers to obtain improvements in end-use electricity efficiency from the kinds of conservation options that are typically identified as targets of opportunity by examining the available data from actual utility program experience and expectations. In answering this question, we also explore the strengths and weaknesses of the methods used by utilities to estimate conservation costs and electricity savings attributable to these programs. We do so by analyzing, within a standardized cost accounting framework, the costs, savings, and measurement methods embodied in conservation program experience and expectations for a sample of electric utilities.[5] Appendix A discusses how the utilities were chosen and the data that were requested from them.

We believe that this analysis is valuable for several reasons. First, the range of cost estimates for various conservation options is very wide. As a result, reasonable people may have very different expectations about the costs of improving energy efficiency and the effects of energy efficiency improvements on the demand for electricity, new generating capacity needs, and the environmental impacts of electricity supply. These differences, in turn, have varying implications for broader energy and environmental policies. If we are going to rely on utilities to capture electricity conservation opportunities that would otherwise be squandered, we need to have a better

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[5] As we discuss, we have not attempted to examine all utility conservation programs for reasons of both time and budget constraints. As a result, the current paper should be viewed as a pilot study.

understanding of the costs and savings associated with actual utility programs. The actual performance of these utility programs is thus the only sensible basis for developing sound estimates of the costs of various conservation options.

Second, the costs associated with energy conservation programs incurred by utilities are passed through to customers in regulated electricity rates. Public utility commissions have an obligation to ensure that these expenditures are being made wisely and that the programs are being designed to encourage customers to conserve at the lowest possible cost.[6] Designing and implementing good conservation programs is much more difficult than first meets the eye. These programs are most productively viewed as efforts by utilities to alter consumer behavior.[7] Viewed from this perspective, responsible energy conservation programs must take account of the wide diversity among customers in demand characteristics, the effects of natural incentives customers have to conserve to save money, asymmetries of information between customers and the utility, retail marketing problems, and the profound difficulties that arise in measuring the actual savings achieved by those customers who participate in utility programs. Programs that are not designed properly to account for these considerations will be wasteful both from the perspective of electricity consumers, who are effectively being taxed

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[6] Industrial consumers have increasingly expressed concerns that the money being spent by utilities on conservation programs is being wasted (Electric Utility Week, November 18, 1991, p. 5). This is ironic since, as we shall see, large commercial and industrial customers are receiving a disproportionate share of the conservation subsidies provided by utilities.

[7] Unfortunately, many regulatory commissions have urged utilities to conceptualize conservation opportunities as equivalent to "supply-side" resources. The conceptualization places regulators and utilities on a path that is sure to lead to wasteful expenditures. For an elaboration of this point see, e.g., Joskow (1988).

to pay for these programs, and society at large. Our examination of actual utility programs provides an opportunity to identify the strengths and weaknesses of utility program design, cost accounting, and electricity savings measurement at an early stage in the evolution of these programs, so that significant imperfections can be taken into account in future program design.

The paper proceeds in the following way. In Section II we present the analytic framework within which we will examine the conservation costs reported by utilities. In Section III we discuss the Lovins and EPRI energy conservation "supply" curves within this framework. In Section IV we present our analysis of the conservation costs reported by a sample of utilities. In Sections V and VI we discuss a range of infirmities that afflict utility conservation cost accounting and energy savings estimation, respectively. In Section VII, we present a detailed discussion of a particularly important issue: the treatment of free riders. In Section VIII we summarize our conclusions and make recommendations for improving the planning, evaluating, and accounting of utility conservation programs.

II. ANALYTIC APPROACH

Throughout this paper, our focus will be on the life-cycle cost of energy conservation investments <u>before</u> taking into account the savings in electricity costs resulting from conservation. That is, we examine the costs of utility conservation programs in this paper, but not their benefits. We take this approach for two reasons. First, this is the framework that has been adopted by Lovins, EPRI, and many conservation advocates in order to provide a simple method for comparing directly the cost of "supplying" conservation with the cost of supplying electricity. Second, as a practical matter, it is much easier for the outside analyst to calculate conservation costs than it is to calculate net benefits; calculating the latter would require significantly more information regarding program, customer and utility characteristics.

Our focus throughout will be on utility conservation programs exclusively, i.e., programs whose primary purpose is to reduce energy consumption. We do not analyze load management programs, which are designed primarily to shift loads in time, reduce peak loads, and, perhaps, increase off-peak loads, or fuel substitution programs, which are typically intended to substitute natural gas for electricity.

a. The Structure of Utility Conservation Programs

Before presenting a detailed discussion of the specific analytic techniques we use to analyze electric conservation investments and estimate their gross costs, it is useful to describe briefly the process by which utilities attempt to promote improvements in electricity efficiency. The typical utility conservation program is structured in the following way. The utility identifies those end-uses in which it believes that significant untapped cost-effective conservation opportunities exist. For each end-use, it then identifies a set of conservation measures that could potentially tap these opportunities. This set typically includes a wide range of measures for residential, commercial, and industrial customers. Lighting measures are typically included for all sectors. In addition, appliance and weatherization measures are typically included in the residential sector. In the commercial and industrial sectors, HVAC and efficient motor programs are generally included. In the commercial and industrial area, in particular, packages of measures must be tailored to the diverse characteristics of the customers who fall in these groups. While utility programs vary widely in terms of the specific conservation measures they promote and how they are packaged, many of the measures identified by EPRI and Lovins are often included in these programs.

To qualify for inclusion in a program a measure must typically pass some type of "total resource cost" test. That is, the expected total cost of the conservation measure (including both costs borne directly by the utility and costs borne by the customer) must be less than or equal to the present discounted value of the expected electricity supply costs that would otherwise be incurred in order to serve that demand.[8,9] The relevant cost is the "incremental cost" associated with the most economical conservation investment compared to the cost of the conservation decision consumers would have otherwise made but for the effects of the utility's efforts.

Having identified the conservation measures that will be promoted, the utility typically establishes an annual budget for each program, develops a marketing and distribution program, and, increasingly, establishes a monitoring and evaluation program that seeks to measure actual performance (i.e. program cost and benefits) ex post. The programs generally provide a mix of customer information and subsidies to customers who choose to participate. Individual customers who seek to participate in a program will

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[8] In some states, e.g. California, Massachusetts, and New York, regulators require that the utility costs used in this test include additional, imputed costs that are intended to represent the environmental externalities associated with electric generation.

[9] Utility programs also often include "low-income" and other redistributive measures that are not always designed to be economical according to this criterion.

frequently be audited for qualification given estimates of their individual use characteristics and the likely effects of the measure on their electricity use and the associated electricity costs saved.

b. A Framework for Calculating the Cost of Conserved Electricity

As we will discuss in Section IV, our initial calculations of the real cost per kWh saved for different conservation measures and programs will be based on data reported by utilities regarding utility and customer costs and energy savings. These data are of uneven and often uncertain quality; in many cases, they are also incomplete. In this section we present a framework for computing the real cost per kWh saved that incorporates all of the relevant cost and savings variables. Later sections will then discuss how various data problems affect our ability to apply this framework to the available utility data and the resulting implications for the interpretation of the numbers reported by utilities.

The computational framework is quite simple. We seek to calculate the real life-cycle cost per kWh saved (the cost of a "negawatthour") for utility conservation programs. To do so we require information on the following variables:

I - The incremental "total resource cost" of the utility conservation program. This cost includes all direct and indirect costs incurred by <u>both</u> the utility <u>and</u> participating customers in connection with the conservation program. These costs include the incremental costs of the conservation measures themselves, a variety of administrative costs incurred by the utility and transactions costs incurred by customers. The utility's administrative costs include costs associated with promoting conservation, delivering conservation measures, and monitoring and evaluating the results of its efforts.

E - The annual kWh savings that result from customers participating in the conservation program.

r - The real discount rate.[10]

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[10] In what follows we use each utility's real after tax cost of capital as the discount rate for its programs. This follows the typical practice of utilities and their state utility commissions for evaluating the costs and benefits of utility conservation programs. However, it is not at all obvious (continued...)

L = The expected economic life of the conservation investments.

With this information in hand we can compute the real levelized cost of the program (R), defined as the constant real stream of rental payments that, over the life of the conservation measure, is equal to the incremental cost of the conservation investment (I):

$$(1) \qquad I = PDV(R;\ r,\ L)$$

The real life-cycle cost per kWh saved (c), our ultimate objective, is then given by:

$$(2) \qquad c = R/E = \text{cost per kWh saved}$$

As we will discuss in subsequent sections, accounting for all of the relevant costs that should be included in I, estimating the energy savings achieved by the conservation programs (E), and defining appropriate lives for the conservation investments (L) can be quite difficult. Utilities handle these difficulties in a variety of different ways.

c. An Introduction to The Free Rider Issue

In implementing the calculations described above, a number of important issues arise in determining what costs and energy savings to include in the analysis. One of the most important of these issues, the so-called "free rider" problem, derives from the fact that at least some consumers participating in a utility program would, in fact, adopt economical conservation options without the utility's efforts. After all, if the cost of

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[10] (...continued) that this is the correct discount rate to use for these types of projects. For most utilities the real discount rate is in the 4% to 5% range. These values are much lower than the real discount rates used by non-regulated firms or by most residential customers (for estimates of the latter, see Hausman (1979) and Hartman and Doane (1986)).

a negawatthour is anything like what Lovins and EPRI claim it is, many of the conservation opportunities targeted by utilities should be economical for customers even without any subsidies. As a result utilities are likely to be spending some money to get customers to do what they would have done anyway (now or in the future). These program participants are "free riders".

Energy savings and cost figures are often reported by utilities without any adjustment for the impact of free riders. In evaluating the economics of utility involvement in energy conservation, the net cost of conserved energy, after appropriate adjustments for free rider effects, is the proper focus of attention since it measures the actual change in resource use that results from utility activities (in other words, it measures the marginal impact of the conservation activities). Since most utilities do not provide enough information to calculate the net cost of conserved energy properly adjusted for free riders, we first report costs per kWh saved without free rider adjustments.[11] It can be easily shown that this underestimates the true cost of utility conservation programs. We offer a preliminary assessment of the potential magnitude of this bias in Section VIII.

III. LOVINS AND EPRI ESTIMATES OF THE COST OF CONSERVED ENERGY

Before discussing the results of our analysis of utility conservation programs, it is useful to discuss in greater detail the Lovins and EPRI estimates of the cost per kWh saved. The energy conservation "supply" curves (i.e., the curves relating the cost of conserved electricity to the quantity saved) estimated by Lovins and EPRI are displayed in Figure 1. They reflect

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[11] In some cases, this calculation required that we "back out" free rider adjustments already made by utilities. In these cases the free rider adjustments were typically incorrect for our purposes anyway.

their respective estimates of the real incremental "societal" cost per kWh saved associated with adopting more efficient energy conservation measures in a wide variety of applications. If we draw a horizontal line in at the average price of 7 cents per kWh, we can get a very rough sense for the magnitude of the opportunities for cost-effective conservation implied by these estimates.

Both sets of estimates embody explicit and implicit assumptions about the relevant cost and operating characteristic variables discussed in the previous section. We focus on only a few of these assumptions here. First, the numbers reported by both Lovins and EPRI are best characterized as estimates of "technical potential". Both sets of estimates reflect the assumption that the entire stock of each of the appliance/equipment items covered is <u>completely</u> replaced by the most efficient technology that is "available". Both sets of estimates also ignore the opportunity cost of scrapping existing appliances and equipment before they have reached the end of their economic lives. Alternatively, they represent a sort of long run equilibrium that could be thought of as emerging after the existing stock of equipment is replaced; in this view, it must be emphasized that the curves conceal a very important temporal dimension. They also apparently rely on engineering estimates of equipment lives rather than estimates of economic lives. The two may be very different, especially if there is rapid cost-reducing or quality-improving technical change associated with specific conservation measures.

Second, Lovins' numbers reflect only his estimates of the incremental costs of the relevant best practice technology; they do not include the program costs a utility would incur in promoting conservation and monitoring and evaluating the results. The latter, as we shall see, are often quite substantial. Thus, Lovins' numbers must, at best, be treated as an optimistic lower bound on the cost of utility-sponsored electricity conservation. In contrast, the EPRI estimates build in a "retail mark-up" to reflect the fact that utilities do incur costs beyond compensating customers for the purchase of efficient appliances and equipment. This margin is somewhat arbitrary and is based on limited utility experience. Neither set of estimates deals with the impact of free riders.

In examining the Lovins and EPRI cost estimates depicted in Figure 1, the most striking feature is the large disparity between the two curves. As noted earlier, the Lovins figures imply savings of about 70% of U.S. electricity demand at roughly 0.6 cents per kWh saved, while the EPRI figures imply savings of almost 30% at roughly 2.6 cents per kWh saved (this figure assumes that only the programs up through number 13 are implemented; the steep part of the "supply" curve is omitted). A number of other features of the graphs deserve comment as well, however.

In the graph of Lovins' estimates, it is noteworthy that the lighting efficiency improvements are available at a negative gross cost. In other words, the lighting improvements would save money for consumers even before any electrical savings are taken into account. This is possible because Lovins assumes that improved lighting systems, based on long-lived fluorescent bulbs, will last sufficiently long as to avoid future maintenance and replacement costs that more than exceed the incremental cost of the lighting upgrade. If this is true, it indicates that consumers and firms are wasting more than just electricity in their lighting design. Alternatively, it may be taken as a signal of the great optimism implicit in the Lovins estimates. It should be noted, however, that while Lovins has thus tried to account for one effect that may reduce customer costs associated with electricity-using equipment, he, like other analysts, still ignores other costs, in particular transactions costs, that participants in conservation programs may also incur.

In the EPRI graph, the most striking feature is its essentially vertical orientation after an efficiency improvement of about 30%. If this is true, it implies that the amount of cost-effective electric conservation available in the economy is essentially invariant for any cost of electricity above about 4 cents per kWh. We are skeptical that the actual cost of conservation exhibits such an extreme degree of decreasing returns.

IV. WHAT DOES UTILITY DATA TELL US ABOUT THE COST OF A NEGAWATTHOUR?

It came as no surprise to us that it was not an easy task to transform the information reported by utilities to their state regulatory commissions into a set of comparable costs per kWh of electricity saved resulting from these programs. Despite increasing utility involvement in conservation activities, there does not yet exist any standardized method for reporting the relevant data. Indeed, in most cases utilities do not report all of the information necessary to determine the true economic costs of their conservation programs. Much of what is reported is an mix of historical experience and projections of future performance. Furthermore, the assumptions and justifications underlying the information that is provided are often lacking or of questionable validity. What does a negawatt really cost? The honest answer is that neither we nor anyone else really knows with any precision! We do know that it costs more than is suggested by Lovins and EPRI, has a higher variance than implied by their analyses, and is understated in the reports issued by most of the utilities whose programs we have examined.

Given these data limitations, the approach we have taken is to do the best that we can with the data that are available, relying as much as possible on the assumptions made and data reported by the utilities.[12] After computing and discussing the apparent cost per kWh of the electricity that utilities claim has been saved by their programs, we will then go on to discuss missing data and underlying assumptions to better understand what, if

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[12] In some cases, we have made some minor adjustments to the reported utility figures. For example, one utility operated similar programs in consecutive years, but reported customer costs only in the second year. These costs have been used to impute customer costs to the programs in the previous year.

any, biases are contained in the results and to provide guidance for better data reporting, monitoring, and evaluation methods.

Before proceeding to the presentation of our initial computations of the cost per kWh saved revealed by utility program experience and expectations, we ask the reader to keep a number of caveats in mind. First, many utilities do not report all of the utility costs and direct customer costs that should be included in the incremental cost of the affected conservation measures ((I) in the earlier section). Second, energy savings (E) are frequently based primarily on engineering estimates rather than adjusted by ex post measurement of actual changes in consumer behavior. Third, utilities use a wide range of assumptions for the lives of what would appear to be roughly identical conservation investments. Finally, the data reported contain a mix of information based on historical experience and projections of expected future performance.

Table 1 reports the results of our efforts to use the information reported by the utilities to compute the total societal cost per kWh saved resulting from their conservation programs. For the reasons discussed earlier, the reported costs per kWh saved have, to the extent possible, excluded adjustments for free riders and, as a result, are biased downward. (As we shall see, the values are biased downward for other reasons as well.) The results are reported separately for residential programs and commercial/industrial programs along with the weighted average cost per kWh saved for each utility's entire program. In each case the costs reported represent the weighted average of the individual program and measure costs in

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TABLE 1

COST PER KWH SAVED: SUMMARY OF RESULTS

(1991 Cents/Kwh)

UTILITY PROGRAM	RESIDENTIAL		COMMERCIAL/INDUSTRIAL		WEIGHTED AVERAGE	COST ACCOUNTING		MEASURED SAVINGS?
	Average	Range	Average	Range		All Utility?	All Direct Customer?	
1	7.6	3.4 –21.6	6.7	3.0 – 10.3	6.9	Most	No	No
2	4.9	2.0 – 22.3	3.5	1.0 – 17.1	3.8	No	No	Some
3	10.4	3.0 – 15.4	1.9	0.8 – 8.0	2.8	Yes	Yes	Some
4	4.7	0.6 – 33.3	N/A	1.7 – 5.9	N/A	No	Yes	No
5A	22.1	5.2 – 181.4	3.1	2.2 – 9.6	3.3	No	No	Yes
5B	6.8	3.9 – 9.2	4.4	3.7 – 4.6	4.8	No	No	No
5B1	7.6	3.9 – 20.2	6.4	3.1 – 7.3	6.6	No	No	Yes
6	12.4	2.9 – 14.1	1.5	0.2 – 4.7	1.9	No	Yes	No
7	4.8	0.4 – 68.8	1.9	1.3 – 4.9	2.2	No	No	No
8A	7.2	3.2 – 22.1	2.4	1.4 – 18.1	3.0	No	No	No
8B	4.4	2.1 – 12.6	3.6	2.6 – 5.3	3.7	No	Yes	No
9	8.0	4.7 – 163.9	3.5	1.8 – 18.8	4.5	Most	Yes	No
10	3.5	0.3 – 5.5	2.0	1.9 – 2.4	3.0	Yes	No	No
11	-------Inadequate Information To Compute Cost/Kwh Saved-------							
12	-------Indadequate Information to Compute Cost/Kwh Saved-------							
13	-----------No Response To Repeated Requests------------							
EPRI	3.0	0.9 – 3.6	2.3	0.7 – 3.9	2.5	No	Yes	No
LOVINS	< 2.0	–1.8 – 4.0	<0.6	–1.8 – 1.0	0.6	No	Yes	No
NES	2.9	2.0 – 3.9	N/A	N/A	N/A	No	Yes	No
RETAIL PRICE								
1990	8.1		5.1		6.9			

these groups.[13] We also report the range of costs experienced in the sub-programs that make up each category. In the two cases for which such data were made available, we report information for two separate years.

For comparison purposes we also report, where available, comparable numbers reported by EPRI and Lovins, as well as figures reported for a set of residential applications considered in the Bush Administration's National Energy Strategy (NES) (Energy Information Administration 1990). Unfortunately, Lovins' figures are not broken down conveniently between residential and commercial/industrial applications, so we only have rough upper bounds to rely on plus the average for all of the applications that he identifies. Average U.S. retail electricity prices for residential and large commercial/industrial customers are also included for comparison.

Finally, Table 1 also provides information about whether or not a utility has accounted for all relevant utility and direct customer costs that are properly included in the total societal cost of the conservation investments and whether or not the electricity savings estimates for the programs are based on ex post measurement of consumer behavior.

The values reported in Table 1 imply that the estimates of the costs per kWh saved by utility conservation programs reported by EPRI, Lovins, and the NES are significantly lower than what utilities have achieved or expect to achieve in practice. The difference is most striking for residential programs. Every single residential program has an average cost per kWh saved

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[13] As noted previously, our concern is with the net present value cost of these programs. Because of the non-linearities involved in discounting, it turns out that the correct weights to use in calculating weighted average program costs are the net present values of the kWh saved in each program. While the idea of discounting kWh, r ^I(
+' an dollars, may at first appear odd, it is, in fact, a standard tool in calculating the costs of utility conservation programs.

that exceeds the values reported by EPRI, Lovins, and the NES. In some cases the difference is extremely large. Furthermore, there is significant intra-utility variation in the cost per kWh saved across individual sub-programs. Almost every utility has stumbled into at least one conservation effort that costs many times more than predicted by EPRI, Lovins, and the NES.

The results for the commercial and industrial programs are closer to the estimates offered by EPRI, although half of the utility programs cost 50% more than projected by EPRI. Lovins' numbers are too low by a factor of two to ten reflecting, in part, their failure to recognize that, in addition to measure costs, utilities also incur costs to implement and evaluate conservation programs. Again, several utilities have stumbled into commercial/industrial programs that costs substantially more than the high end of the range reported by EPRI.

The figures for the commercial and industrial programs should also be compared to the results of a study by Nadel (1990a; see also 1990b) that surveyed conservation and load management programs at 58 utilities, primarily as of year-end 1988. Nadel found that most commercial and industrial conservation programs had costs of less than 4 cents per kWh, and that a significant number were around 1 cent per kWh. While there are significant differences between his approach and that employed here (he does not include customer costs and he uses his own lifetime estimates rather than those of the utilities, among other differences), our results are clearly in the same ballpark. Some utilities do indeed report program costs in the 1 cent per kWh range, while many report them in the 3 to 4 cent range.

While many of these programs thus appear to be economical, it is clear that the Lovins and EPRI numbers significantly underestimate what it actually costs utilities to "buy negawatts". As we shall see, since many utilities have not accounted for all relevant costs, the actual difference between the costs per kWh saved resulting from utility programs and the numbers reported by EPRI, Lovins, and the NES is likely to be even larger than Table 1 indicates. Indeed, the cost per kWh saved may be understated by a factor of two or more on average.

Another striking feature of the figures in Table 1 is the consistent and significant disparity in the cost per kWh saved between the residential programs and the commercial/industrial programs. Without exception, the utilities report that their residential programs cost significantly more, per kWh saved, than their commercial and industrial programs. This result is consistent with the EPRI estimates, in which residential programs are estimated to cost almost twice as much as commercial/industrial programs.

While this finding indicates that commercial/industrial programs may have a significant edge over their residential counterparts in terms of cost per kWh saved, it is also true that commercial/industrial programs are expected to have a much larger aggregate impact on electricity consumption. As shown in Table 2, for the utilities we surveyed, residential conservation programs make up only about 20% of projected energy savings (and only about 30% of net present value expenditures);[14] the remaining 80% of energy (and 70% of costs) derive from the commercial/industrial programs. This finding differs sharply from the EPRI analysis, in which some 32% of energy savings (and 38% of costs) derive from residential conservation.

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[14] These figures would be significantly lower, on the order of 13% of energy from the residential sector, were it not for the one outlier, Utility 10, at which residential energy is 68% of the total. Utility 10 is the only utility in our sample at which expected residential energy savings exceed those of the commercial/industrial sector.

TABLE 2

SECTORAL DISTRIBUTION OF COSTS AND ENERGY SAVINGS

	NPV COSTS		NPV ENERGY SAVED	
Utility Program	Residential	C&I	Residential	C&I
1	21%	79%	19%	81%
2	28%	74%	20%	80%
3	36%	64%	10%	90%
4	N/A	N/A	N/A	N/A
5A	5%	95%	1%	99%
5B	22%	78%	15%	85%
5B1	22%	78%	19%	81%
6	25%	75%	4%	96%
7	22%	79%	10%	90%
8A	32%	69%	13%	87%
8B	19%	81%	16%	84%
9	43%	58%	24%	76%
10	79%	21%	68%	32%
Weighted Average	30%	70%	20%	80%
EPRI	38%	62%	32%	68%

Given these findings with regard to both cost per kWh saved and total kWh saved, the utility data appear to indicate that the potential for large economic and environmental benefits from energy conservation lies not in the residential sector, but in the commercial and industrial sectors.

It is also clear from the results in Table 1 that there is significant variability in costs per kWh saved among the various utilities. These differences can be traced to several factors. First, and of great importance, are the significant differences in cost accounting and energy savings estimation that exist among the utilities. As Table 1 indicates, only two of the utilities account for all of the relevant utility and direct customer costs in their reports.[15] Cost accounting and energy savings estimation issues will be examined more closely in Sections V and VI, respectively. Second, there are, perhaps, systematic differences among the energy markets within which the utilities operate. For example Utility 10 has much lower electric rates than does Utility 1 and a much greater penetration of electric space heating. Third, the values reported in Table 1 are based on measure lives and energy savings estimates reported by the utilities. As we shall see presently, there is sometimes significant variation among utilities in assumed measure lives for what are roughly the same pieces of equipment. These differences are difficult to understand, but they can have very large implications for the cost per kWh saved. Only three of the utilities base their savings estimates on ex post measurement techniques. Finally, there are real differences between the program selection, marketing, and delivery

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[15] We are only in a position to determine whether or not the utilities made an effort to account for all of the relevant costs by including an appropriate entry in their reports. We cannot determine whether they have actually measured the relevant costs accurately.

techniques used by the utilities.

In addition to examining the sectoral and aggregate costs reported by utilities, we have also examined the costs incurred at a more disaggregate level for a set of specific conservation initiatives that are common to many of the utilities. Table 3 reports the results for six types of programs that are commonly pursued by utilities: Residential Appliances (Refrigerators and Freezers), Residential Lighting, New Residential Construction, Commercial and Industrial Lighting, Commercial and Industrial Motors, and Commercial and Industrial New Construction.

It is important to understand that utilities generally package various measures together so that they can conserve on auditing and marketing costs and capture all of the significant electricity conservation opportunities located in an establishment. As a result, most conservation measures are delivered as part of conservation packages, rather than as single elements (this is particularly true of some of the New Construction programs which target all electricity-using equipment in a new building). This makes direct comparison of the utility costs with the EPRI and Lovins estimates somewhat tricky, since these latter are estimated at the level of specific devices or end-uses. This is even true for the categories, such as appliances, lighting, and motors, that correspond fairly well with measure categories identified by EPRI and Lovins as potential sources of large savings. The same caveat also applies, although to a lesser extent, to comparing the costs of particular program types across utilities. Utilities structure their programs differently, and thus programs in the same end-use category may have significantly different costs and performance.

The figures reported in Table 3 parallel those reported in Table 1. For

TABLE 3

COST PER KWH SAVED: SELECTED PROGRAMS

(1991 cents/kWh)

UTILITY PROGRAM	REFRIG/ FREEZER	RESID LIGHTING	RESID NEW CONSTRUCTION	EFFICIENT MOTORS	COMMER LIGHTING	COMMER NEW CONSTRUCTION
1	10.5	6.2	21.6	N/A	N/A	10.3
2	N/A	2.7	22.3	1.0/17.1	1.8	2.7
3	N/A	N/A	N/A	1.3	0.8	N/A
4	4.8	5.0	3.6/6.6	1.7/2.0	5.1/5.9	2.0
5A	181.5	20.8	N/A	N/A	2.3/10.0	2.2
5B	4.4	8.6/9.2	5.3	N/A	4.5	3.7
5C	4.4	9.2/20.2	5.3	N/A	7.1	3.1
6	8.1	2.9	2.9	1.2/2.8	1.5	N/A
7	68.8	16.7	15.1	N/A	1.4	3.3
8A	N/A	19.4	N/A	N/A	1.4	18.0
8B	N/A	5.5	12.5	N/A	3.7	2.6
9	3.9/11.0	4.9	163.9	3.5/4.1	2.5	18.8
10	N/A	0.8	1.6 – 3.5	N/A	2.2	2.4
EPRI	3.3	0.9	N/A	2.7	1.4	N/A
LOVINS	N/A	<0.0	N/A	<1.0	<0.0	N/A
NES	3.9	N/A	N/A	N/A	N/A	N/A

residential applications, the EPRI, NES, and Lovins numbers significantly underestimate the actual costs reported by utilities. For commercial and industrial programs the EPRI numbers are closer to and fall within the range of values computed for utility programs. Lovins' numbers, on the other hand, are low by a very significant margin. We should recall as well, that in most cases the values reported in Table 3 do not include all relevant utility and direct customer costs and, as a result, tend to be underestimates. It should be clear, however, that despite the fact that these programs do not live up to Lovins' expectations, in many cases utilities are successful in promoting efficient motors, efficient commercial lighting, and the construction of new energy efficient buildings at what appear to be very low costs relative to the price and cost of the electricity that is saved even if we allow for significant under reporting of costs.

The residential programs are clearly more problematical. Several of these programs do not appear to be economical or, at best, are marginally economical. Indeed, some of the values reported are astronomical. The figures for utility refrigerator and freezer conservation programs are noteworthy both for their variability, and, in two cases, for their sheer magnitude.[16] Further, the reported costs are underestimates of the appropriate cost per kWh saved since customer costs are not included.

One reason why residential programs fare so poorly is that some components of these programs are designed to achieve distributional goals rather than cost-effective energy efficiency goals. It has become common for

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[16] These two cases are both appliance labeling programs. The results show that such programs are simply not appropriate for most utilities. They should be implemented over a much larger geographic area to take advantage of the economies of scale inherent in such programs.

utilities to be required to implement programs that are specifically designed to improve the electric efficiency of low-income households. From an efficiency perspective, it is often argued that such households are particularly likely to suffer from market imperfections and thus may provide one source of substantial conservation possibilities. In addition, it is also argued that improving the electric efficiency of low-income households is an appropriate method for achieving distributional goals.

In a number of cases, utilities plan and evaluate their low-income programs on a different basis from that used to analyze programs designed to be cost-effective. In particular, a number of utilities do not use a strict cost-benefit test to determine whether low-income programs should be pursued. As a result, such programs are likely to produce improvements in electricity efficiency at a higher cost than would programs that are designed to meet a strict cost-effectiveness test. As can be seen from Table 3A, there is some tendency for low-income programs to be more expensive than other residential programs. However, this is far from a universal result. In any case, it is clear that the low-income programs are by no means the sole reason that residential programs are so costly.

In Table 3 we also continue to observe substantial variation in the cost per kWh saved even for very similar sub-programs. Thus, the variations we observed in Table 1 are likely to be primarily a consequence of the factors identified above (cost accounting, measure lives, savings measurement, program implementation), rather than a result of differences in the composition of individual utility programs.

TABLE 3A

LOW-INCOME RESIDENTIAL PROGRAMS

(1991 cents/kWh)

Utility Program	Low-Income Programs	Other Residential Programs	Residential Total
1	6.3	8.8	7.6
2	9.5	4.4	4.9
3	N/A	10.4	10.4
4	5.4	4.5	4.7
5A	20.8	30.4	22.1
5B	8.6	6.5	6.8
5B1	20.2	6.4	7.6
6	2.9	12.7	12.4
7	46.0	3.6	4.8
8A	22.1	7.0	7.2
8B	4.2	4.4	4.4
9	11.6	5.7	8.0
10	1.6	3.6	3.6

V. UTILITY COST ACCOUNTING

The results reported in Table 1 and Table 3 represent the real cost of a kWh expected to be saved by utility conservation programs based on the information made available by utilities to their state regulatory agencies. In reviewing the utility information in the course of calculating the numbers reported in these tables, it became clear to us that all of the cost information necessary to calculate properly the total resource cost of these programs was frequently not reported, or was reported in ways that were not useful for our purposes. Further, utility cost and energy accounting procedures differ significantly from one another. As a result, some of the variation in the values reported in Tables 1 and 3 reflects the fact that some utilities neglect to include more of the relevant costs than do others. In order to understand some of the infirmities in utility cost accounting procedures, it is necessary to explore in more detail exactly what costs are relevant for computing properly the cost per kWh saved by utility conservation programs.

As we discussed earlier, the costs reported in Table 1 depend on four key variables: the aggregate utility and customer costs incurred to achieve the conservation savings (I), the economic lives of the associated investments (L), the energy saved by these investments (E), and the real discount rate (r).[17] In this section we will explore the appropriate components of the aggregate utility and customer costs (I).

The figures used by utilities for (I) should properly include the following elements:

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[17] The real discount rates used by utilities are within a sufficiently narrow range that we will not discuss discount rate issues in this paper.

K_d - The total direct installed cost of a specified conservation measure. This cost will be shared in some way between the utility, the consumer, and, in some cases, third parties[18].

K_a - Total direct costs incurred by the utility to implement specific conservation subprograms over and above direct measure costs. These costs include advertising, marketing, and other promotion, as well as monitoring and evaluation costs. Since the latter such costs often occur a number of years after installation, this figure should be interpreted as including the net present value of the relevant stream of such costs.

K_o - An appropriate share of those administrative "overhead" costs allocable to a utility's conservation activities. These costs include office space and administrative support, conservation planning, executive and legal costs, and some portion of regulatory preparation costs.[19]

A_d - The total direct installed cost of the energy-using equipment that a customer would otherwise install in the absence of the utility program.

O - The net present value change in other costs resulting from the adoption of the more efficient device.[20]

The relevant incremental resource cost (I) of a utility conservation program is then given by:

$$I = K_d + K_a + K_o + O - A_d \tag{3}$$

The foregoing definitions assume that the electricity customer faces a

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[18] A typical third-party bearing some of the costs would be a public housing authority.

[19] These are administrative costs that cannot easily to assigned to specific subprograms within the portfolio that makes up the utility's overall conservation program.

[20] Typical examples include incidental savings of natural gas and heating oil that occur in houses that receive building shell improvements and the reduced maintenance costs that may sometimes be associated with more energy efficient appliances and equipment. Any change in the end-use satisfaction (e.g., reduced lighting) could also be included here.

choice between purchasing a standard device and a more efficient device having the same expected economic life. In fact, in a number of cases, in particular retrofit applications, the real economic decision is between operating an existing device (e.g., an old motor), or scrapping it in favor of a new efficient one. In such cases, it is necessary to impute a remaining scrappage value to the retired equipment. This value would add to the cost of the program. While such costs should be included in practice, they are particularly difficult to estimate and will be ignored in this paper.[21] For the remainder of the paper, we will also ignore the other cost category (O), as this makes up a very small portion of costs reported by utilities (of course, like scrappage costs, this category might turn out to be significant if we could track it carefully).

Table 4 summarizes some of the significant attributes of the information regarding costs and energy savings that are reflected in the data that we used to compute the cost per kWh saved figures reported in Table 1. Of particular interest to us in this section are the categories of significant costs that are not reported by various utilities; in Section VI we will focus on the methods used to estimate and verify energy savings.

a. Missing Utility Costs

It is evident from Table 4 that utilities frequently do not report all of the costs that they have, or will, incur as a result of their conservation programs. The costs associated with direct marketing and installation of

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[21] Of the utilities in our survey, only one appears to have adjusted its cost figures for this issue. In its motor rebate program evaluation, Utility 6 analyzed cases in which customers replace a failed motor or an operating one. Replacement of an operating motor was assumed to cost significantly more.

TABLE 4

CHARACTERISTICS OF UTILITY PROGRAM EVALUATION DATA

Utility Program	Utility Costs				Customer Costs		Measured Savings Adjust
	Direct	Admin	Eval		Measure	Other	
1	Yes	Yes	Partial		Partial	No	No
2	Yes	Partial	Yes		Partial	Yes	Yes
3	Yes	Yes	Yes		Yes	No	Partial
4	Yes	Partial	No		Yes	No	No
5A	Yes	Partial	Partial		No	No	Yes
5B	Yes	Partial	Partial		No	No	No
5B1	Yes	Partial	Partial		No	No	Yes
6	Yes	Partial	Partial		Partial	Partial	No
7	Yes	Partial	No		No*	No*	No
8A	Yes	Partial	No		No*	No*	No
8B	Yes	Partial	Yes		Yes	Yes	No
9	Yes	Partial	Partial		Yes	No	No
10	Yes	Yes	Yes		No	No	No
EPRI	Yes	Partial	No		Yes	No	No
NES	Yes	Partial	No		Yes	No	No
RMI	Yes	No	No		Yes	Yes	No

* The utilities did not include these cost elements in their analyses. However, estimates of these costs could be generated from the data for program 8B. These estimates are included in the figures presented in this study.

program measures, including customer incentive payments and some degree of auditing, are generally reported by the utilities. However, many types of administrative costs, including the future measurement and evaluation of conservation savings, are not universally tracked and reported by the utilities. The exclusion of such costs can lead to significant underestimates of the cost per kWh saved resulting from conservation investments.

Two cost items tend repeatedly to be ignored by utilities. These items are measurement/evaluation costs and various administrative and overhead costs that would not be incurred in the absence of the utility conservation programs. Given the difficulty of accurately measuring the electricity savings resulting from utility conservation programs (see Section VI), measurement and evaluation activities are likely to become significant cost elements in utility conservation programs. As yet, not all utilities have recognized these costs in their planning. Administrative and overhead costs include everything from the opportunity cost of office space used by the conservation staff and associated building services to planning, legal, and executive resources used to design programs, monitor their implementation, and defend them in regulatory proceedings to the extent that these costs would not be incurred in the absence of one or more conservation programs. With only three clear exceptions, these administrative and overhead costs were not clearly allocated by utilities to their conservation program costs. Because of these exclusions, it is likely that the utility portion of the costs used in developing Tables 1 and 3 are understated for some utilities. Thus, the actual costs of conservation are likely to be higher than is reported in these tables.

In order to get a better feeling for the potential magnitude of the missing costs it is useful to divide costs reported by utilities into two categories: direct expenditures on conservation measures by both the utility and customers (K_d - A_d) and implementation, monitoring, measurement, and administrative costs (K_a + K_o), which we will refer to simply as administrative costs for simplicity in what follows. In Table 5, we report estimates of the ratio of administrative costs to measure costs as reported by seven utilities in our sample, as well as for EPRI ($[K_a + K_o]/[K_d - A_d]$). The costs reported by other utilities could not be disaggregated into direct measure costs and administrative cost components.

The figures display many of the same characteristics as the cost data reported in Table 1. In particular, they display a significant degree of variability between utilities, especially for residential programs. In addition, the administrative cost fractions in the residential sector are with only one exception higher than the corresponding fractions in the commercial/industrial sector, in contrast to EPRI's assumptions.

In interpreting these figures, two caveats should be kept in mind. First, some utilities, as will be discussed in greater detail below, do not report the full customer portion of direct measure costs. To the extent that this occurs, the figures in Table 5 will overstate administrative costs as a fraction of direct measure costs. On the other hand, as just discussed, not all utilities report all the administrative costs that ought to be allocated to conservation programs. To the extent that this is true, the figures reported in Table 5 will be underestimates of the administrative to direct cost ratio.

As it turns out, two of the utilities with the best - i.e., most complete - customer cost data (utilities 3 and 9) have the two highest overall

TABLE 5

REPORTED ADMINISTRATIVE COSTS AS A FRACTION OF DIRECT MEASURE COSTS

Utility Program	Residential	C&I	TOTAL
1	48%	42%	44%
2	12%	5%	7%
3	261%	31%	70%
4	30%	30%	30%
5A	–	–	–
5B	–	–	–
5B1	–	–	–
6	11%	11%	11%
7	–	–	–
8A	–	–	–
8B	–	–	–
9	480%	40%	107%
10	29%	48%	33%
EPRI	20%	27%	25%
LOVINS	0	0	0
NES	0	N/A	N/A

ratios of administrative to direct measure costs. The low ratios of utilities 2 and 6, on the other hand, may well be due to incomplete tracking of utility administrative costs. The EPRI figures and those reported for utility 4 are merely projections and do not reflect actual program activity. Both are based on a study by Berry (1989) in which administrative costs for commercial and residential programs were estimated to be in the 20% to 30% range, based on a review of the experience of three utilities. Based on our results, a 30% administrative cost fraction appears to be at the low end of a reasonable range for the commercial/industrial programs. While the data are far from conclusive, it would appear that such a figure would understate, perhaps by a great deal, the administrative cost burden of residential programs, however.[22]

Taken together, these facts indicate that administrative to direct cost ratios are likely significantly higher than assumed by EPRI in its cost projections. In the commercial/industrial sector there is ample evidence of administrative to direct measure cost ratios of 30% to 50%, while in the residential sector, ratios are likely to be even higher. Moreover, it should be emphasized that for certain subprograms, administrative costs may make up an extremely large share of total costs. For such programs, the exclusion of administrative costs in cost analysis would be particularly misleading.

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[22] In his study, Nadel (1990a) found that, for 46 utilities reporting such costs, "indirect" costs (what we have called administrative costs here) averaged 36% of <u>utility</u> direct measure costs for commercial/industrial programs. Since this study excluded consideration of customer costs, the implied value for the administrative to direct cost ratio is some lower value. Our results indicate that a ratio of the same magnitude (30% to 40% or more) is more likely to be at the low end of the appropriate range when applied to <u>total</u> direct measure costs.

b. Missing Customer Costs

Customer costs fall into three general categories. The first includes the direct incremental costs associated with purchasing and installing the various conservation measures. In some cases the utility pays the full incremental cost of the measures, but in other cases the customers, or a third-party, pay a share of these costs. The second category includes the transactions costs borne by customers. The latter costs include time spent shopping, with energy auditors, and dealing with those who install the measures (e.g. waiting at home for the electrician to show up and keeping your eye on him to make sure he doesn't steal the silver). They also include the value of lost business and inconvenience incurred while the measures are being installed. Transactions costs are real costs that should in principle be taken into account when calculating the cost of conservation measures. In an ordinary market context, of course, it would be the individual consumer that would take these transactions costs into account when making purchasing and investment decisions. The third category, closely related to the first, includes the value of any existing devices that may need to be scrapped in order to participate in the utility program. These may include the usage value of a second refrigerator in an appliance turn-in program or the undepreciated value of an operating motor that is scrapped in order to take advantage of a utility rebate program. If these costs are not reported by utilities then the costs per kWh reported in Tables 1 and 3 will be understated. We examine the accounting treatment of each category of costs in turn.

In a typical program, utility incentive payments made to customers for the installation of efficient devices do not cover all of the direct incremental costs (I) of the conservation measures. Thus, the utility and the customer share in the cost of improved efficiency. As a result customer costs must be added to utility costs in order to determine the total resource cost of the conservation programs.[23] Unfortunately, few utilities perform adequate tracking of the costs incurred by participants in their programs. In our sample of utilities, only four appeared to track customer costs in a rigorous manner. Even in these cases, moreover, the utility was sometimes unable to track costs in certain programs.

When a utility is subsidizing a conservation investment in order to alter customer behavior, it is important to know whether the subsidies are serving partially to compensate consumers for bearing transactions costs. If there are no customer transactions costs then utility subsidies can simply be treated as a transfer payment which merely determines who pays what fraction of K_d - A_d. However, if the subsidies are compensating consumers for bearing transactions costs they would not have otherwise borne, then the portion of the subsidy that is compensation should be treated as an additional cost. We do not make this calculation here, but merely notes its relevance.

None of the programs attempt to measure customer transactions costs. This is not surprising since such costs would be very difficult, if not impossible, to measure. Yet customer transactions costs are very real economic costs that should in principle be accounted for in evaluating the societal cost of utility conservation programs (as anyone who has stayed home all day waiting for the electrician to show up for a 9 AM appointment will understand).

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[23] There is no double counting here. If the customer makes the conservation investment and is then provided with a subsidy by the utility, the customer cost is computed by subtracting the incentive payment from the total measure cost.

With the one exception noted previously, none of the programs that we reviewed take account of the remaining life of existing appliances and equipment. For retrofit applications this failure could lead to a significant underestimate of the incremental cost of conservation since it assumes that the customer would have purchased a new less efficient piece of equipment immediately rather than, say, five years from now. While the failure to take customer replacement decisions into account tends to bias the estimates of the cost of conserved energy downward, this is not as serious a failure as first meets the eye. When utilities compute the benefits associated with the conservation investment they also assume that the customer would have replaced his existing equipment with a new model immediately. To the extent that the model the customer is assumed to acquire absent utility subsidies is more energy efficient than the existing equipment, the failure to take remaining lives into account will also overestimate the energy saved by the adoption of more energy efficient conservation measures.

c. Summary of Cost Bias Results

All of the cost biases in utility accounting for the costs of conservation appear to point one way. As a result, the costs per kWh reported in Tables 1 and 3 understate the true costs of these programs, perhaps very substantially. Without seeking to diminish the importance of this result, which appears unassailable, we should note one (partially) mitigating factor. Many (though by no means all) of the energy conservation programs are still in their early years. There are undoubtedly start-up costs and inefficiencies in implementation, associated with the creation of such programs; these will tend to show up in our cost estimates, but may not continue as programs mature and benefit from learning by doing.

VI. UTILITY ESTIMATES OF ENERGY SAVED

The real costs per kWh saved reported in Tables 1 and 3 are obviously quite sensitive to the underlying estimates of energy savings. Most serious analysts recognize that it is quite difficult to measure accurately the energy savings resulting from utility conservation efforts. These difficulties arise because of the diversity in customer utilization patterns, changes in these utilization patterns over time, the limited information a utility has about both the base level of and changes in the utilization of individual participants, differences in characteristics between participants and the population upon which "typical customer" utilization data are based, changes in behavior induced by conservation, etc.

In some cases it is possible to obtain good savings estimates by using statistical methods to compare utilization patterns of participating customers with those of similar non-participating customers. Such an approach requires, however, the careful identification of appropriate control groups, collection of data on all relevant customer characteristics, and careful monitoring of consumption and changes in customer characteristics for the treatment and control groups over a sufficient period of time to capture all relevant behavioral changes. In other applications, especially when there are significant idiosyncratic customer specific characteristics, it may be very difficult to make accurate measurements of savings. What is clear is that measurement of savings requires careful thought, extensive data collection, careful analysis, time, and (probably) a lot of money.[24]

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[24] For a much more detailed discussion of the issues that arise in conservation program evaluation, the reader is referred to a recent pair of reports from EPRI. EPRI (1991a) provides an overview of conservation evaluation techniques, including relevant statistical and econometric methods; the companion

(continued...)

A related difficulty involves the use of engineering models to forecast the energy savings of conservation programs. It has not been uncommon for ex post evaluations to reveal that these ex ante engineering estimates were significantly overstated. Studies done in the mid 1980s, for example, found that residential weatherization programs in the Pacific Northwest produced only 50% to 80% of the aggregate savings estimated by engineering models (National Economic Research Associates (1987), pp. 38-64, and references therein). Monitored programs for two utilities in New England have revealed savings of only 27% to 33% of engineering estimates (Anderson (1991) and Northeast Power Report (1991)). We have come across no studies where engineering estimates yielded significantly smaller energy savings than were realized based on ex post measurement techniques.

Despite the obvious problems and difficulties associated with relying on engineering estimates of energy savings, most of the utilities in our sample continue to base their projections of costs and benefits on such estimates. Of the few that use some types of ex post evaluations to measure actual savings, only utility 5 provided enough data to allow a systematic comparison of the results with the ex ante engineering forecasts. This utility, which has undertaken a serious effort to measure the actual savings achieved by its programs, found that actual savings in 1990 were only 68% of the savings predicted by engineering estimates.

Most utilities acknowledge that techniques to monitor and measure actual savings have not advanced very far and that more work is needed to do so. An

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[24] (...continued)
volume (EPRI 1991b) discusses some case studies in which various techniques were used. The reports have extensive lists of references, and thus are useful guides to the literature.

increasing number are expanding their measurement and monitoring efforts. However, the failure to integrate sample selection, data collection, and analysis into the design of the conservation programs themselves makes it more difficult to come up with sound estimates of actual savings. At this point, we must conclude that, at best, the savings estimates reported by many of the utilities in our sample are unsupported by sound measurement of the actual responses to their programs. In addition, based on existing *ex post* measurement efforts it would not be surprising if energy savings reported significantly overestimate actual energy savings. This in turn implies that the costs per kWh saved reported in Tables 1 and 3 are likely to be underestimated as well. If the 68% ratio of measured savings to engineering estimates experienced by one utility is representative, it would imply that costs per kWh for estimates based on engineering models alone would be about 50% higher than what is reported in these tables.

b. Conservation Measure Lives

The cost of a conservation option can be very sensitive to the assumed life of the measure. The appropriate way to measure the life of a conservation option is to measure its *economic* life, i.e., the number of years that a customer will actually continue using the appliance or equipment in its intended use. Economic lives are likely to be less than the physical engineering life of a piece of equipment. This is particularly likely to be true when cost-reducing or quality-improving technological change is rapid or where customers can easily substitute another piece of equipment (e.g.

TABLE 6A

ASSUMED LIVES FOR COMMON MEASURES
Residential Programs
(Years)

Utility Program		Efficient Lighting	Appliance	New Construction	Blitz	Efficient Water Heater	Water Heater Wrap
1		14	14	15	12	–	–
2		6	–	30	–	–	6
3		–	–	–	15	–	–
4		3	15	20	–	15	–
5		4	15	–	3.7	–	5
6		–	15	22	–	10	–
7		7	15	26	–	–	8
8		7	15	26	–	–	8
9		7	20	25	–	–	10
10		2	–	70	–	–	–
EPRI		8	20	20	–	10	–
NES		–	19	–	–	13	–

TABLE 6B

ASSUMED LIVES FOR COMMON MEASURES
C&I Programs
(Years)

Utility Program		Light	Motors	New Cons	HVAC
1		15	15	15	–
2		7	15	12–15	–
3		10	20	–	17
4		10	10	20	–
5		14	30	20	–
6		17–20	20	–	–
7		16	10	18	–
8		16	10	18	–
9		5–20	12–17	25	–
10		20	–	37.5	–
EPRI		10	20	15	–

residential lighting).[25,26]

The sources of the lives used by utilities in selecting conservation measures and designing programs are typically not well documented. By and large, however, the lives appear to be engineering lives based on standard manuals of physical lives for some "typical" population of consumers. In some cases these lives appear to have been adjusted based on information drawn from actual customer behavior. The use of engineering estimates of measure lives is troublesome. Engineering lives are rarely equal to the actual economic lives of appliances and equipment. Nor is there any reason to believe that program participants have the same characteristics as the average consumer for whom an engineering estimate of measure life is computed.

Our concerns about the reliance on engineering estimates of measure lives, indeed about the reliability of the measure lives assumed by the utilities in our sample, is reinforced by the substantial variation across utilities in the measure lives that are assumed (and imbedded in the cost calculations reported in Tables 1 and 3) for similar measures. Table 6 displays the measure lives assumed by several of the utilities in our sample for several common conservation measures. The degree of variability in

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[25] The fact that a light bulb may have a physical life of 8 years is not relevant for computing costs if a significant fraction of the participants remove the bulbs completely or place them in closets where they are used only a few hours a year.

[26] As a technical note, we should also point out that the common use of mean measure lives in conservation cost analyses systematically overstates energy savings, and thus systematically understates the cost of conservation. This happens because the measure of energy savings used in the cost analysis is actually the net present value of electricity saved. It can be easily shown that the net present value of a stream of energy savings resulting from measures of varying lifetimes is less than the net present value of the stream of energy savings that results when all measures are assumed to last exactly the mean lifetime. Based on some numerical simulations, this effect appears small (on the order of 1%), however, and is ignored here.

assumed lifetimes is sometimes quite striking. It is hard to imagine that an efficient lightbulb last seven times longer in residences in Utility 1's service area than it does in Utility 10's service area, or that an efficient lightbulb lasts three times longer in commercial establishments in Utility 2's service area than it does in Utility 10's service area.

Some of this variation can be explained by legitimate differences in the measures installed. For example, commercial lighting packages typically include a mix of fluorescent bulbs, efficient ballasts, and other devices such as reflectors, occupancy switches, etc. To a certain extent, the differences in assumed measure lives may reflect different utility assumptions about the mix of long-lived ballasts (on the order of 15-20 years) with short-lived bulbs (6-14 years); of course, we are then left with the question of why the utilities have such a range of assumed mixes. Some of the variation may also represent actual differences in operating usage. It seems entirely reasonable to suppose, for example, that the expected lifetime of motors varies significantly with the type of local industry. However, we believe that it is unlikely that the large variation in assumed measure lives that we observe can be explained primarily by such factors.

We have no way to know what the correct operating lifetimes are for the various measures in utility conservation programs. However, we believe that a significant portion of the variability in utility assumptions regarding operating lifetimes indicates that they don't know either. In order to get a sense for the potential impact of changing operating lifetime assumptions on the cost per kWh saved reported in Tables 1 and 3, we have done the following rough calculation. For each of the programs reported in Table 3 we have recalculated the levelized costs of conservation using the longest and

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TABLE 7A

COST PER KWH SAVED: SELECTED RESIDENTIAL PROGRAMS

Sensitivity To Variations In Measure Lives

(cents/kWh)

UTILITY PROGRAM	REFRIG/ FREEZER			RESID LIGHTING			RESID NEW CONSTRUCTION		
	Reported	High	Low	Reported	High	Low	Reported	High	Low
1	10.5	10.5	8.6	6.2	30.3	4.9	21.6	21.6	13.8
2	N/A	N/A	N/A	2.7	7.1	1.2	22.3	30.5	19.5
3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	4.9	5.1	4.1	5.0	7.3	1.1	3.6	4.3	2.4
5A	181.4	190.4	150.6	20.8	37.1	5.2	N/A	N/A	N/A
5B	4.4	4.6	3.6	8.6	28.1	3.9	5.3	8.4	4.4
5C	4.4	4.6	3.6	20.2	66.1	9.2	5.3	8.4	4.4
6	8.1	8.5	6.8	2.9	19.9	2.9	2.9	3.6	2.0
7	68.8	71.9	59.7	16.7	50.5	8.5	15.1	19.4	12.8
8A	N/A	N/A	N/A	19.4	58.5	9.8	N/A	N/A	N/A
8B	N/A	N/A	N/A	5.5	N/A	N/A	12.6	N/A	N/A
9	11.0	13.6	11.0	4.9	14.8	2.3	163.9	209.4	126.5
10	N/A	N/A	N/A	0.8	0.8	0.1	3.5	6.5	3.5
EPRI	3.3	4.2	3.3	0.9	3.1	0.4	N/A	N/A	N/A
LOVINS	N/A	N/A	N/A	<0.0	N/A	N/A	N/A	N/A	N/A
NES	3.9	4.7	3.8	N/A	N/A	N/A	N/A	N/A	N/A

Note 1: High value reflects short life and low value reflects long life.

TABLE 7B

COST PER KWH SAVED: SELECTED COMMERCIAL PROGRAMS

Sensitivity To Variations In Measure Lives

(cents/kWh)

UTILITY PROGRAM	EFFICIENT MOTORS			COMMER LIGHTING			COMMER NEW CONSTRUCTION		
	Reported	High	Low	Reported	High	Low	Reported	High	Low
1	N/A	N/A	N/A	N/A	N/A	N/A	10.3	11.6	7.1
2*	17.1	22.2	14.7	1.9	1.9	1.0	2.7	2.7	1.6
3	1.3	2.1	1.3	0.8	1.1	0.5	N/A	N/A	N/A
4	2.0	2.0	1.3	5.1	6.8	3.2	2.0	2.8	1.5
5A	N/A	N/A	N/A	10.0	17.2	7.9	2.2	3.0	1.6
5B	N/A	N/A	N/A	4.3	6.5	3.0	3.7	4.6	2.4
5C	N/A	N/A	N/A	6.9	10.6	4.9	3.1	3.9	2.1
6	2.8	4.4	2.8	1.4	3.0	1.4	N/A	N/A	N/A
7	N/A	N/A	N/A	1.4	2.5	1.3	3.3	4.1	2.6
8A	N/A	N/A	N/A	1.4	2.5	1.3	18.1	23.2	14.6
8B	N/A	N/A	N/A	3.7	N/A	N/A	2.6	N/A	N/A
9	4.1	4.9	3.1	2.6	4.9	2.4	18.8	19.6	11.5
10	N/A	N/A	N/A	2.2	4.7	2.2	2.4	4.4	2.4
EPRI	2.7	3.7	2.3	1.4	1.9	0.9	N/A	N/A	N/A
LOVINS	<1.0	N/A	N/A	<0.0	N/A	N/A	N/A	N/A	N/A
NES	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note 1: High value reflects short life and low value reflects long life.

*Utility #2 also has a motor program in the 1 cent/kWh range.

shortest lifetimes reported by any utility for that program type. As should be clear, the long lifetimes result in low costs of conservation, while the short lifetimes result in high costs. These results are reported in Tables 7A and 7B.

In interpreting the figures in these tables, it is important to keep in mind the non-linear relationship that exists between estimated costs and operating lifetimes. While halving the estimated operating life of a measure reduces the estimated physical kWh of energy saved by 50%, it reduces the net present value of the lifetime stream of energy savings by significantly less. As one would expect, this affect is more pronounced the longer the lifetimes in question. Thus, a halving of estimated operating lifetimes leads to less than a doubling of estimated costs per kWh.

Table 7A reports the results for the three residential programs for which we have the data necessary to do the calculations. For refrigerator/freezer programs the effects of varying lifetime assumptions within the high/low range is fairly small at about 25%. For residential lighting programs the difference is much larger, more than a factor of six. For residential new construction programs the variation in costs is in the middle, roughly 75%, reflecting the fact that, while there is substantial variation among the assumed measure lives, even the shortest life is quite long.

Table 7B reports similar results for three commercial/industrial programs. For efficient motor programs the low lifetime assumption increases the estimated cost per kWh saved by roughly 60% over the high lifetime assumption. For commercial lighting the difference is closer to 100% and for commercial new construction the difference is about 75%, essentially the same as that for residential new construction.

For five of the program types, variations in assumed lifetimes lead to variations in the realized cost per kWh that range from about 25% to about 100%; for residential lighting programs, however, the variation is so great, and the shortest life so short, that the highest costs are more than six times the lowest. Clearly, credible estimates of the costs of utility conservation programs require much more credible information on measure lives.

VII. FREE RIDERS

The existence of free riders in utility conservation programs creates special difficulties both for measuring savings and for cost accounting. When utilities spend money to get participation from customers who would have adopted the conservation measures on their own, the utility is effectively spending money and receiving no social benefit from these expenditures. To the extent that the utility spends real resources to attract, monitor, and evaluate free riders (as opposed to merely making transfer payments) there is a net social loss. The proper way to compute the social cost per kWh saved from utility conservation programs requires that energy savings attributable to free riders not be credited to the conservation program and that measure costs (K_d - A_d) incurred by free riders and the utility not be counted as a cost of the program. Thus, developing the costs per kWh saved that properly make adjustments for free rider effects requires estimating the degree of free ridership in a program and adjusting cost and energy figures to reflect the estimated free ridership.

a. Utility Estimates of Free Riders

While most of the utilities in our sample recognize, at least verbally, that they ought to account for free riders in their program evaluations,[27] only six actually include free rider estimates for significant components of their programs in their cost-benefit analyses. Table 8 displays these assumed free rider fractions for a set of conservation measures.[28]

The most striking feature of Table 8 is the fact that there are not many entries in it. While free rider issues have received a great deal of discussion by utilities and their regulators, little progress appears to have been made in estimating empirically the fraction of participants in utility conservation programs who are free riders. Another striking feature of Table 8 is that some programs have very high free rider fractions. In these cases, it appears that an active market for conservation may already exist; if so, it is questionable whether these market segments are appropriate targets for utility subsidies.

While the six utilities reporting free riders differ somewhat in how they incorporate them in cost-benefit analyses, the five of them that have undertaken evaluations do share a common approach to estimating free riders:

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[27] A number of utilities also emphasize the potential existence of so-called "free drivers", consumers who choose to adopt efficient technologies because of a utility program but do not actually participate in the program. While the existence of such consumers is, of course, plausible, we have seen little evidence that they are a significant side benefit of utility programs. In particular, the claim made by some utilities that free drivers likely offset free riders seems both arbitrary and extremely unlikely. For some evidence regarding free drivers, the reader is referred to EPRI (1991b, in particular p. 2-16) and references therein.

[28] It must be emphasized that the level of aggregation used affects the reported free rider fractions significantly. For example, at the micro level some "programs", e.g., the promotion of particular HVAC types, may have free rider fractions approaching 100%. At the macro level, e.g., commercial/industrial retrofits, however, the same free riders may appear much smaller. The figures in Table 8 are intended to represent a middle ground, neither too micro nor too macro.

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TABLE 8

FREERIDER ASSUMPTIONS

Utility	Residential Programs					Commercial/Industrial Programs				
Program	Lighting	Appl.	New Cons	Wat Ht	Air C.	Lighting	Motors	New Cons	Other	HVAC
1	–	–	–	–	–	–	–	–	–	–
2	–	–	–	25–40%	–	21%	55%	–	–	–
3	–	–	–	–	17%	27%	8%	–	–	43%
4	–	–	–	–	–	–	–	–	–	–
5A	–	–	–	–	–	4–21%	5–62%	–	–	–
5B,5B1	–	–	–	–	–	4–21%	5–62%	–	–	–
6	–	–	–	–	–	–	–	–	–	–
8A	–	–	–	–	–	34–40%	–	–	4–8%	–
8B	–	–	–	–	–	34–40%	–	–	4–8%	–
7	–	–	–	–	–	23–25%	–	–	4–8%	–
9	–	30% (some)	2%	–	–	30%	30%	2%	30%	30%
10	–	–	–	–	–	–	–	–	–	–
EPRI	–	–	–	–	–	–	–	–	–	–
NES	–	–	–	–	–	–	–	–	–	–
LOVINS	–	–	–	–	–	–	–	–	–	–

the use of surveys designed to determine what prompted participation in a program. Free riders are typically assumed to be those participants who report that they would have undertaken the conservation investment even in the absence of the utility program.[29] The fraction of participants thus categorized as free riders is then typically used to adjust proportionately the energy savings of the program and, in some cases, certain of the program costs.

A potentially serious problem with this approach is that it fails to recognize that free riders may well have utilization characteristics significantly different from the average participant. That is, free riders are not just a random draw from the population of customers for whom the conservation option is cost effective. In particular, free riders are likely to be customers for whom the economics of choosing the "appropriate" conservation option are most favorable (e.g. long hours of use, long expected life, short life of existing equipment, relatively low installation cost, etc.). All else equal, this would imply that free riders, on average, save more per participant than non-free riders. If this is true, it implies that using the fraction of participants identified as free riders to adjust costs and energy savings will bias downward the estimates of the net cost per kWh saved.

Unfortunately, the data tracked by the utilities have provided little basis for testing these propositions. One utility did collect data that

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[29] It is beyond the scope of this paper to enter into a discussion of the problems associated with designing good surveys and the use of survey results to calculate free rider rates. Moreover, utilities appear generally aware of the difficulties in designing and implementing good survey instruments. Thus, we ignore the general issue of using surveys to estimate free ridership. Instead, we will concentrate on the specific question of how the survey results are used to develop free ridership estimates.

provide some insight into this issue, however. In evaluating two of its programs, Utility 2 used the proportion of energy savings attributable to free riders, rather than the proportion of participants identified as free riders, as the basis for adjusting reported costs per kWh. Since the utility also tracked the proportion of participants identified as free riders,[30] it is possible to compare these two methods of estimating free ridership for these two programs.

As part of its evaluation of its motor rebate program, the utility conducted a survey that allowed for participants designated as free riders to be cross-tabulated with the size of motor purchased and its expected hours of use per year. The utility found that 42% of the participants were free riders. However, the free riders accounted for 55% of the energy saved by all participants. In this program, then, the fraction of energy savings attributable to free riders is significantly more (13 percentage points) than the fraction of participants identified as free riders.

The opposite result occurred in a second evaluation, this time of a commercial lighting rebate program. In this case, the utility performed a survey, cross-tabulated with energy use projections, to estimate that 27% of participants, but only 21% of energy savings, were attributable to free riders. In this case, the use of a participant free rider fraction rather than an energy free rider fraction would overstate the impact of free ridership. These two cases suggest that the assumption that free riders have identical characteristics to the average participant may be a poor one and that efforts to collect free rider information should include both the

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[30] These fractions were not reported in the evaluation reports, but were kindly provided to us by a representative of the utility.

identification of free riders and their utilization characteristics.

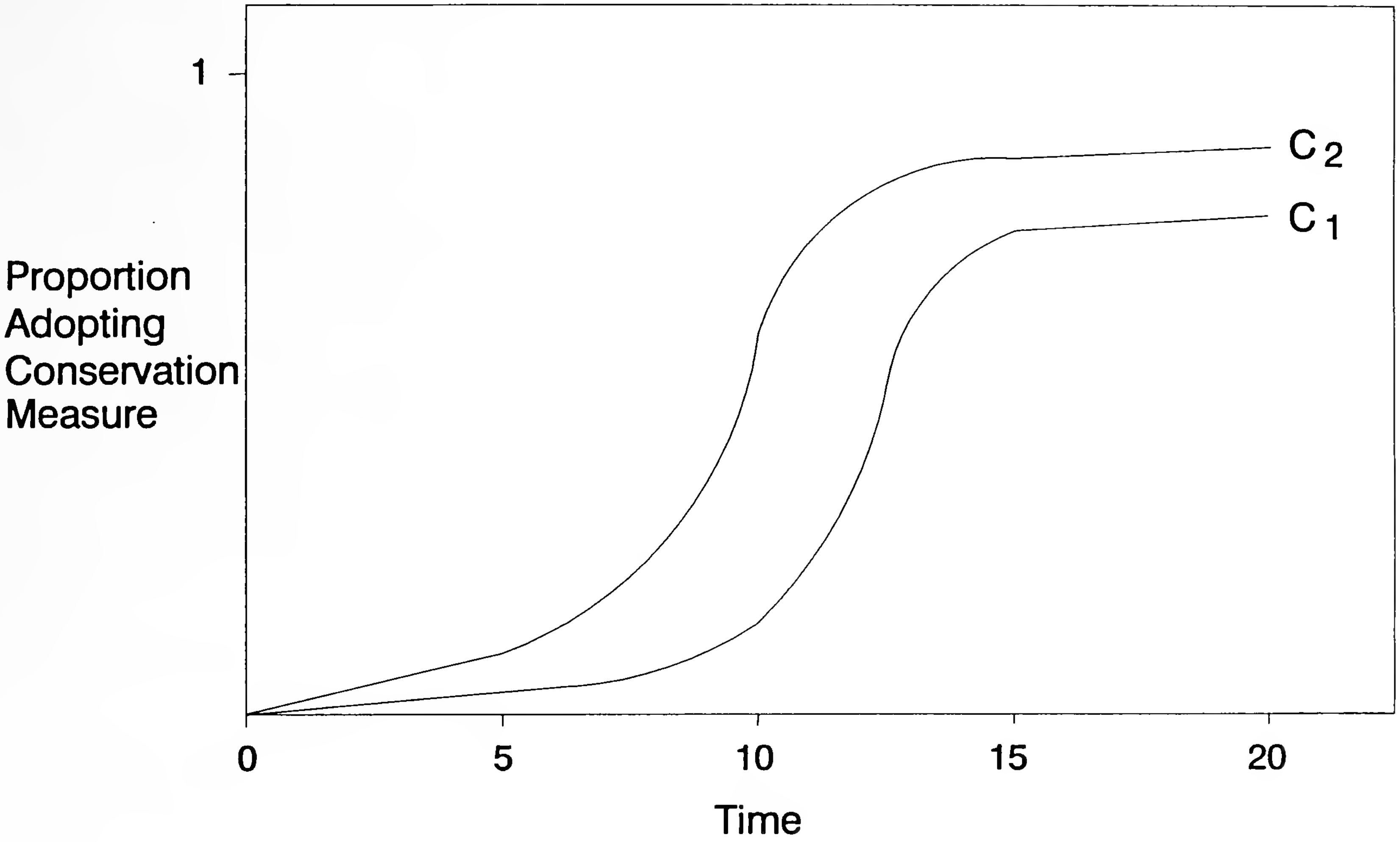
b. Free Riders and Diffusion Patterns

To this point we have focused on free riding as essentially a static problem. In fact, free riding is properly conceptualized not as a simple static decision "but for" utility subsidies, but in terms of shifts in the diffusion curve for the relevant pieces of equipment and appliances. Thus, in principle, free riding should capture both the effects of utility programs on the timing of adoption of efficiency measures (earlier rather than later) and on the equilibrium penetration levels. Figure 2 displays hypothetical diffusion curves for efficient commercial lighting with and without a utility program. The curve C_1 depicts the fraction of existing commercial buildings that would install efficient lighting over time in the absence of the utility conservation program. After ten years 70% of the buildings are assumed to have installed these devices. The curve C_2 is a hypothetical diffusion curve for efficient lighting after taking account of the utility's conservation program. The conservation program does two things. It speeds up diffusion, and it increases the maximum penetration rate achieved after ten years.

From this perspective, free riding is not an all or nothing phenomenon. It is not just a question of whether some of this year's participants would have adopted a conservation measure absent the utility's program, but when they would have adopted the measure. Assume for example that a utility survey indicates that none of the participants would have adopted a measure with a ten year life this year and, therefore, assumes that the free rider effect is zero. However, if all of the participants would have installed the measure two years from now in the absence of the program, the static approach will

Figure 2

Hypothetical Conservation Diffusion Curves



significantly overestimate the actual savings achieved by the program this year. Rather than achieving ten years of energy savings for each participant the program actually only yields two years of energy savings. In general, the failure to account for dynamic diffusion effects appears to lead to overestimates of energy savings and underestimates of the cost per kWh saved.

The proper measurement of free riders raises many of the same sample design and statistical analysis issues as are created by the challenge of measuring energy savings more generally. Utility efforts to measure free riders are just beginning to evolve and are still quite crude. No effort has been made even to conceptualize the free rider measurement problem in the dynamic diffusion context depicted in Figure 2. Ignoring these effects biases downward the computed values of the cost per kWh saved reported in Tables 1 and 3.

c. The use of free rider estimates in calculating net costs

Once they have estimated free ridership, utilities typically proceed to adjust their cost and energy savings estimates to account for these free riders. Such adjustments are typically accomplished by multiplying estimated energy savings by one minus the free rider fraction and then using this "net energy saved" figure to compute the benefits of the program. In our notation, this is equivalent to replacing E in the denominator of equation (2) by E times one minus the free rider fraction (FR). Note that statistical techniques that compare participant usage with that of non-participants may perform a similar adjustment, even if the effect of free riders is not estimated separately. In some cases, utilities also subtract the free riding <u>customers'</u> share of the expenditures on conservation measures from I in

TABLE 9

INCREASE IN COST/KWH SAVED DUE TO FREERIDER ADJUSTMENTS

Free–Riders	Administrative Costs as a Fraction of Direct Measure Costs								
	25%	50%	75%	100%	125%	150%	175%	200%	All
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
10%	2%	4%	5%	6%	6%	7%	7%	7%	11%
20%	5%	8%	11%	13%	14%	15%	16%	17%	25%
30%	9%	14%	18%	21%	24%	26%	27%	29%	43%
40%	13%	22%	29%	33%	37%	40%	42%	44%	67%
50%	20%	33%	43%	50%	56%	60%	64%	67%	100%
60%	30%	50%	64%	75%	83%	90%	95%	100%	150%
70%	47%	78%	100%	117%	130%	140%	148%	156%	233%
80%	80%	133%	171%	200%	222%	240%	255%	267%	400%
90%	180%	300%	386%	450%	500%	540%	573%	600%	900%

equation (3).

This approach does not properly account for the conservation costs attributable to free riders. When free riders are removed from the analysis both the energy savings attributable to them and all incremental measure costs (both customer and utility) should be subtracted as well. In this way we remove from the analysis all utility costs that are transfer payments and any measure costs incurred by the free riders, since these would have been incurred anyway. The traditional approach has the effect of biasing the cost per kWh saved upward. While this problem does not affect the numbers in Tables 1 and 3, since these do not include free rider adjustments, the point should be kept in mind when analyzing other reports of conservation costs.

To illustrate the potential effect that appropriate adjustments for free riders may have on the costs per kWh saved reported in Tables 1 and 3, we have performed a set of simulations whose results are reported in Table 9. The simulations assume that we can divide the incremental costs of conservation (I) into two components: measure costs (K_d - A_d) and other "administrative" costs incurred by the utility (K_a + K_o). We then compute the appropriate net (of free riders) cost per kWh saved by making several adjustments to the energy savings and incremental cost values in equations (1), (2), and (3). First, we multiply the estimated gross energy savings (E) by (1-FR) to get the net energy savings (E'). Next, we compute the associated incremental societal cost as $I' = I - FR*(K_d - A_d)$ (i.e., we eliminate the incremental measure costs attributable to free riders). Substituting these values in equations (1) and (2), we then obtain the net cost per kWh saved (c').

Table 9 displays the ratio of the adjusted cost per kWh saved (c') to the unadjusted cost per kWh saved (c) for various assumptions about the free

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TABLE 10

SELECTED ESTIMATES OF RATIO OF ADJUSTED TO UNADJUSTED COST PER KWH SAVED

Utility	Program	Admin Cost/ Measure Cost	Free Riders	Adjusted/ Unadjusted Cost/kWh Saved
2	Water Heater Wrap	22%	25%	1.06
	Retrofit Motors	173%	55%	1.77
	Retorfit Lighting	10%	21%	1.02
3	Central AC Rebate	82%	17%	1.09
	Commerc Audits	22%	4%	1.01
	Lighting Rebate	52%	27%	1.13
	HVAC Rebate	38%	43%	1.21
	Motor Rebate	241%	8%	1.06
10	Appliance Rebates	90%	18%	1.10
	Various Comm Programs:	10%	30%	1.04
		50%	30%	1.14
		100%	30%	1.21
		180%	30%	1.28

rider fraction and the ratio of administrative costs to measure costs. The "All" column refers to the case when the only costs of conservation are administrative. In addition, they represent the results of using the common technique of dividing total program costs (including costs associated with free riders) by energy savings that do not include free riders.

As is clear from the table, the larger is the free rider fraction, the more the unadjusted costs need to be increased to reflect the true social costs per kWh saved. It is only when all costs are administrative, however, that the necessary adjustment is as large as that implied by the "divide total costs by energy net of free riders" approach. Similarly, the larger is the ratio of "administrative" costs to measure costs, the higher is the cost per kWh saved, since these real cost outlays by the utility (rather than transfer payments) must be recovered over a smaller number of kWh. In evaluating the efficiency of a program it is thus not enough to know the free rider fraction alone. We need to know both the free rider rate and the administrative cost component of the utility's program.

From the table, we see that free riders are clearly not much of a problem when both the free rider fraction and the administrative cost ratio are relatively small. As both increase the failure to adjust for free rider effects leads to much more significant biases in estimates of the cost per kWh saved. The question, of course, is where utility programs actually tend to be. Only three utilities provided enough information to estimate the bias from failing to adjust for free riders. Table 10 reports estimates of the free rider fraction, the ratio of administrative costs to direct measure costs, and the associated ratio of adjusted costs to unadjusted for the programs for which we have sufficient information. It is evident that, for this sample, the unadjusted costs per kWh could be understated by as little as 1% or as much as 77%.

It should be noted that the fundamental problems associated with measuring energy savings in general, and free ridership in particular, are by no means peculiar to the area of electricity conservation; indeed, they are likely to arise in a number of important policy areas. A similar problem arises whenever economic agents are to be paid an incentive to do what they might have otherwise done anyway. This problem is inherent, e.g., in proposals that emitters of CO_2 be allowed to offset those emissions (if they are regulated in the future) by reforestation projects. The cheapest source of reforestation, from the polluter's point of view, will be from timber companies that would have planted the trees anyway. An offset system will thus need some mechanism for distinguishing a "true" incremental tree from a "free rider". Similarly, proposals to reduce pressure on over-harvested fishing stocks sometimes include the idea of paying incentives to boat owners to retire from the business. Such incentives will clearly be most attractive to the marginal producers, i.e., those that would have stopped producing anyway.

The basic point, then, that should be taken from this analysis is that the design of incentive regulations systems, particularly in the environmental area, must take care to understand the informational structure within which agents will respond to the incentives. If agents have a significant amount of private information, they may be able to take advantage of the system without providing the benefits it was designed to produce.

IX. CONCLUSIONS

The goal of this paper was to answer the question "What does a negawatt really cost?" Despite all of the rhetoric suggesting that electricity savings from conservation expenditures are "too cheap to meter", the available evidence suggests that we don't really know with a great deal of precision, at least in part because the savings are not being "metered" properly. What we can say is the following:

1. Computations of the cost per kWh saved from utility conservation programs, derived entirely from the data on costs and energy saved reported by utilities, suggest that the cost of a "negawatt" is substantially higher than is generally thought based on standard references such as Lovins and EPRI. This is especially true for residential programs where computed costs are much higher than proponents of utility conservation programs have suggested. Most utilities have pursued at least some subprograms in both the residential and the commercial sectors where the cost per kWh saved is very high and the associated expenditures are clearly uneconomical.

2. There is very wide inter-utility variation in the cost per kWh saved. This variation exists even when we narrow our focus to subprograms with very similar characteristics. While this variation may reflect differences in economical conservation opportunities and the effectiveness of individual programs, it is unlikely that these explain more than a small part of the variation. A large part of the variation probably results from differences across utilities in the costs that they measure and report, differences in assumed measure lives, and differences in the way energy savings are measured.

3. The costs per kWh saved that we reported in Tables 1 and 3 are likely significant underestimates of the true cost per kWh saved. This downward bias is due to the failure to report all relevant costs, the reliance on engineering estimates of savings rather than ex post measurement of actual savings, and the failure to make adjustments for free rider effects. Further biases may result from adopting measure lives that are too long. It is difficult to know exactly how large this downward bias is, but we would not be surprised if the reported costs per kWh saved understate the actual costs per kWh saved by a factor of two or more on average.

4. It is unlikely that conservation is nearly as large a "free lunch" as many proponents of electricity conservation programs have suggested. Public policy enthusiasm for utility conservation programs will have to be tempered by the reality that, when all relevant costs are acknowledged and we actually "meter" it, electricity conservation is not nearly as cheap as is often advertised.

5. Utility sponsored conservation programs are more costly than proponents have argued in part because utilities are intermediaries between customers and measure suppliers and must spend significant sums of money over and above the direct costs of conservation measures to deal with fundamental problems of asymmetric information and adverse selection. Many of the costs a utility must incur would not have to be incurred by an individual consumer motivated by self-interest to invest in cost-effective conservation. Thus utility conservation programs should not be viewed as a substitute to stimulating more conventional private market responses to conservation opportunities.

6. There do appear to be significant conservation opportunities that can be achieved economically by utilities, especially in the commercial and industrial sector. However, in order to better refine program designs, costs, and savings, it is quite clear that utilities still have a lot of progress to make with regard to measurement and accounting for all relevant costs, accurate measurement of the electricity savings that their programs are achieving, and measurement of free rider effects.

7. Since utility expenditures on conservation are not necessarily "too cheap to meter," and the costs incurred by utilities are rolled into the (higher) rates we all pay as a consequence of these programs, utilities and their regulators must pay more attention to proper cost accounting, the development of better techniques to measure electricity savings achieved by the programs, and measurement and accounting for free rider effects.

8. Free riders do matter, though not so much as some standard free rider adjustments would lead one to believe. Both energy savings <u>and</u> costs should be adjusted to reflect free ridership. Program evaluations that ignore free riders will understate the true costs of energy conservation, while evaluations that adjust only energy savings, but leave costs unchanged, will overstate the true costs of conservation. Given the heterogeneity in usage characteristics that may exist among participants, free rider estimates based only on the proportion of participants that are free riders may be misleading.

10. Utility data indicate that the potential for large-scale, cost-effective electric conservation is dominated by the commercial and industrial sectors.

Insofar as we find it easier to believe that residential consumers, rather than corporate ones, are likely to face a variety of barriers to making investments in energy efficiency, we find this result surprising. Indeed, we believe that many people visualize conservation programs as being designed to help residential consumers. As the corporate orientation of conservation programs becomes more widely known, we would not be surprised to see some sort of backlash against them among consumer advocates and residential ratepayer groups.

We believe that there are a number of steps that utilities and their regulators can take to develop better, more credible and verifiable conservation programs. These steps include:

1. We agree with Hirst (1989) that it is important to develop and disseminate a standardized conservation cost and energy savings reporting system, analogous to the existing FERC system for reporting financial data and supply related information. However, because conservation programs have characteristics that make them quite different from supply side resources, the development of a comprehensive cost measurement and accounting system must be developed in conjunction with the definition of all of the elements required to compute the costs and benefits of utility conservation programs. We have identified the kinds of cost information that should be collected. The proper <u>measurement</u> of each of these cost elements requires further work, however. Since a few utilities have managed to account for all of the relevant cost items, there is no reason why all utilities could not quickly agree on which utility and customer cost data are relevant.

2. The reliance on ex ante engineering estimates of energy savings achieved by conservation programs is simply unacceptable. There is abundant evidence that there can be significant variations between ex ante predicted savings and ex post measurement of actual savings. Utilities have experience measured savings that are as low as 30% of ex ante savings estimates. If significant sums are to be spent by utilities on conservation programs, a great deal of progress needs to be made in the development and use of sampling techniques and statistical analysis to estimate what impacts conservation programs actually have had on electricity utilization. The measurement problem may be difficult to solve in many cases, but it must be addressed more aggressively. There is significant virtue in moving forward with collective efforts to develop measurement techniques and the necessary data rather than relying on each utility to develop its own measurement methods and its own data. The recent EPRI reports (1991a, 1991b) are an good start in this direction.

3. It is unacceptable to ignore free rider effects. Consumers have powerful incentives to invest in conservation when the cost of conserving is significantly less than the bill savings that result from having to pay for less electricity. When utilities spend money to convince customers to do what they would have done anyway without these efforts, they are wasting scarce resources. While there is no doubt that some market imperfections keep conservation from achieving its full potential as rapidly as would be desirable in an ideal world, market mechanisms can and do stimulate conservation by consumers. Efforts to understand better the dynamics of consumer behavior and to measure free rider effects should be an important part of all utility conservation programs.

4. Good conservation programs, and appropriate accounting and measurement methods, will only evolve if they are designed and implemented using an appropriate conceptual framework. Many of the problems with existing programs are, in part, a consequence of the erroneous conceptualization of conservation investments as "supply sources" that has been promoted by many conservation advocates and accepted by many state regulatory commissions. Conservation investments are a "supply source" only in the trivial sense that if there is less demand then less supply will be required to balance supply and demand. Thinking about conservation in this way is the road to ruin for good program design and implementation.

The proper rationale for utility conservation programs is that they are mechanisms to ameliorate information, financial and other market imperfections that lead consumers to fail to make cost-reducing investments. It must be recognized that good programs should be designed to break down these market barriers and market imperfections. They should seek to alter consumer behavior by improving customer information, increasing customer incentives, and stimulating the evolution of markets that do not yet exist. They should not seek to create costly utility and regulatory bureaucracies that permanently replace these market mechanisms. Ideally, as these market barriers are removed the role of the utility should recede as it is replaced by better functioning market mechanisms that rely on the self-interest of individual consumers to reduce their electric bills. Utility programs should be designed with these "make the market work" goals in mind.

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Appendix A: Selection of Utilities

We wrote letters to a dozen utilities requesting information about the characteristics, costs, analytical assumptions, and measurement techniques associated with their conservation programs. In order to avoid confidentiality problems we asked that information be provided which was publicly available and that had been or would be provided to state regulatory agencies. These particular utilities were chosen because they were identified as having "good" conservation programs by experts with whom we spoke. Information from this set of utilities was supplemented by similar information obtained earlier from two additional utilities which we had relied on to formulate our survey questions. The utilities in our survey universe plan to spend over $700 million on conservation programs in 1991.

All but one of the utilities responded to our requests for information. Two of the responding utilities did not have or would not provide us with all of the information required to calculate the life-cycle cost per kWh saved associated with their programs. Several responding utilities provided us with additional follow-up information beyond our initial requests and were extremely helpful in assisting us in understanding their programs. In two cases we obtained conservation program information for two utilities that were part of the same holding company. In one of these cases the programs for the two affiliates were so similar that we analyzed only one of them. In the other case the programs were sufficiently different that we analyzed the results separately. In two cases (utility 5 and utility 8) we had information for two time periods and have reported separate computations for each (5A, 5B and 8A, 8B) for each time period. In one case we were able to adjust projected values for the most recent program period (5B) with information on measured energy savings that had not been available when the utility put its program data together (5B1).

The data provided to us from utilities is an uneven mix of historical experience, projections adjusted for the utility's historical experience, and simple projections made by the utility based on engineering data and experience of other utilities. As a result, the numbers that we are able to compute are a mix of actual utility experience and projections of what utilities think the conservation programs will cost and achieve.

Although we did not promise confidentiality, and no utility requested confidentiality, we have decided, for now, not to identify the results of our analysis with the individual utilities from whom we obtained information. The details of utility conservation programs have increasingly become contentious regulatory issues. The purpose of our project was not to point any fingers at particular utilities and we do not want our work to be used in this way. Further, we are making this Working Paper available for comment to the utilities that provided us with information and revisions may be required in light of their comments. We do feel that is appropriate, however, to list the utilities in our original survey universe, including those that did not provide adequate information to us. Those utilities are:

Boston Edison
Central Maine Power
Connecticut Light and Power (NU)
Western Massachusetts Electric (NU)
Long Island Lighting
Massachusetts Electric (NEES)
Metropolitan Edison (GPU)
Pennsylvania Electric (GPU)
New York State Electric and Gas
Northern States Power
Pacific Gas & Electric Company
Puget Sound Power & Light
Southern California Edison
Wisconsin Electric Power

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